3D Radar Signature Visualization of Air Vehicles

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One of the challenges in displaying radar signature data is to present the data in an intuitive way so that the radar return levels identify the source of the radar returns. This paper describes a method of visualizing radar signature data using three-dimensional computer aided design (CAD) models.

Radar signature data can be presented in one dimension, as a dBsm level as a function of vehicle aspect angle. In a synthetic aperture radar image, data is presented in a two-dimensional image: as an intensity level represented by a color located in both vehicle down range and cross range. When the radar antennas are translated both vertically and horizontally, radar data is located three-dimensionally in down range, cross range, and vertical range. This is useful because it provides for a more precise location of point scatters, which would aid a technician tasked to repair a signature flaw. The point scatterer can be identified precisely because the ambiguity in vertical range is eliminated. Also, clutter due to ground bounce and bounce off of the ceiling can be separated from vehicle returns in the vertical dimension.

The Office of Naval Research and the Naval Air Warfare Center, Weapons Division, Advanced Antenna Technology Branch, China Lake, California, developed the Miniature High Speed Radar, or MHSR, used for collecting this 3D data. Sensor Concepts, Inc., Livermore, California, developed the 3D software. The data was collected using a T-38 at Edwards AFB, and a BQM-74E target drone at Naval Air Station Point Mugu.

The radar is a low-power linear FM homodyne radar, and is especially suited for collecting radar signature data of vehicles inside untreated hangars, due to its low output power and high accuracy. The MHSR was set up to image the aircraft at X-band, around a 10 GHz center frequency. Bandwidth was 3 GHz for the BQM-74E measurement, with a 20 ft by 30 ft by 30 ft image zone, and 2 to 3 inch resolution. Bandwidth was 1 GHz for the T-38 measurement in order to provide a larger image zone, and resulted in 5 to 6 inch resolution.

The T-38 was imaged while sitting on its landing gear in a maintenance hangar at Edwards AFB, as shown in Figure 1. Radar absorbent foam was used to block the return from the landing gear. The positioner translated the radar antennas 5 ft horizontally and 5 ft vertically.

The BQM-74 target drone was measured inside a maintenance hangar at Point Mugu. The drone was placed on a 5 ft column of expanded polystyrene foam. Radar absorbent foam was used to decrease the ground bounce in front of the drone.
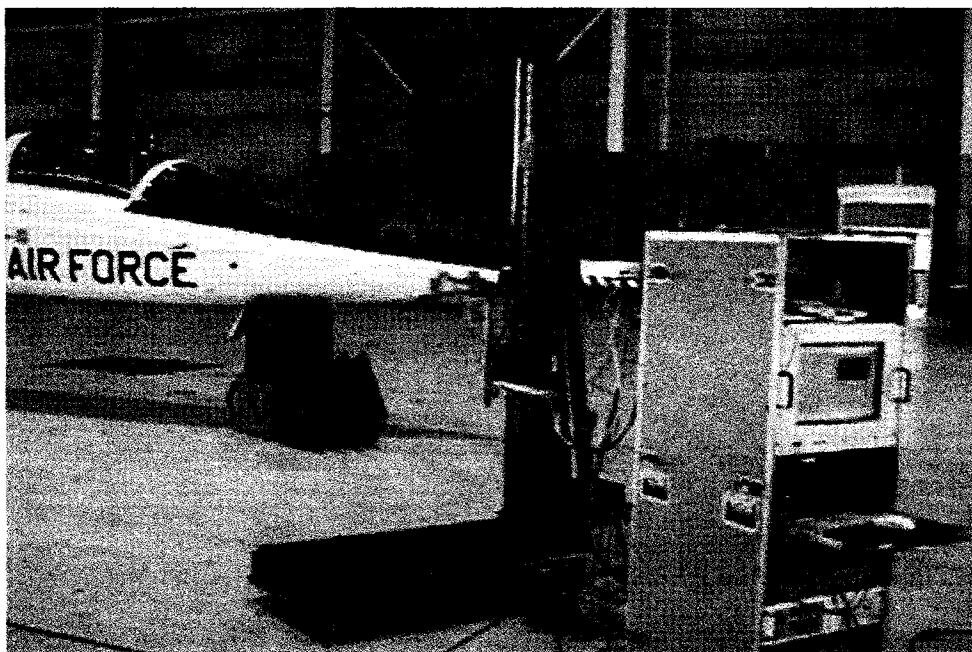
Figure 1 The radar and positioner in place to measure the T-38 in the hangar.

The 3D computer-aided design model was in the common .3ds file format. The number of facets is a measure of the complexity of CAD models. The T-38 model, shown in Figure 2, had over 2000 facets. The models were complex enough to accurately represent the aircraft without being so complex as to unnecessarily slow down the software that mapped the returns to the surface of the CAD model. The software used to create, manipulate, and display 3D models was VRT: a virtual reality software that is available commercially from Superscape.
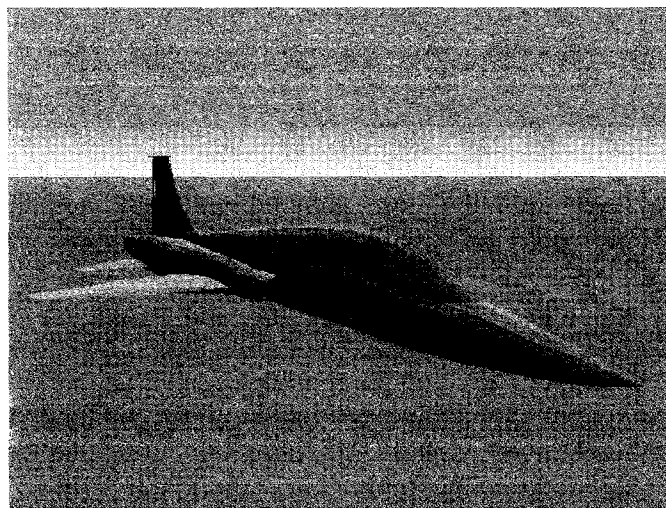

Figure 2. The 3D CAD model of the T-38 as depicted using VRT software.

The 3D-image visualization process, depicted in Figure 3, begins by creating or importing the CAD model of the aircraft into the VRT virtual reality software. The 3D CAD model is aligned to the 2D overlay used to map the MHSR data in cross range and down range. Then the data

collected by the MHSR is defined in cross range, downrange, and vertical range. The data is then mapped where it intersects with the CAD model surface, using a texture approach as shown in Figure 4. The texture approach maps pixels of color based on the resolution size of the radar data rather than only one color per CAD model facet. This approach permits depiction of the radar data to be independent of the CAD model facet size.
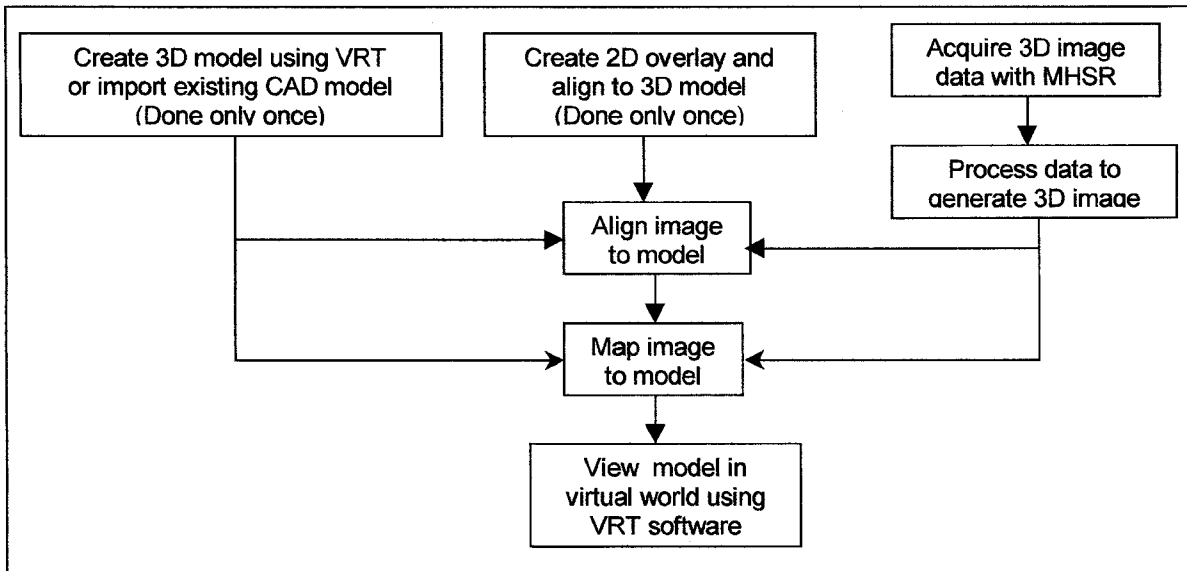

Figure 3. Procedure used to map radar signature data on a 3D model.
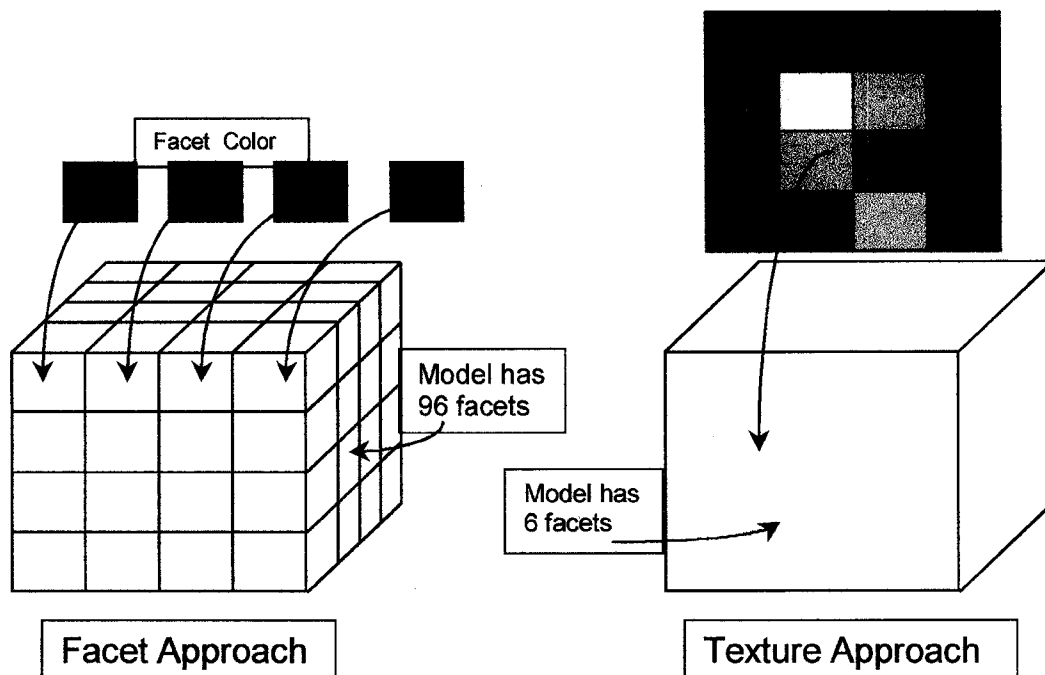

Figure 4. The texture approach to mapping colors to the 3D model is independent of facet size.

The VRT software then creates bitmaps of the pixels that map onto the facets of the CAD model. The VRT software also provides the capability to view the CAD model in 3D perspective and show it from any viewing angle.

Shown in Figure 5 is a typical 2D image created from MHSR data showing the outline of the T-38 in cross range and downrange. Note that all returns in vertical range collapse onto the display plane. Some radar return could come from reflections from the ceiling or floor, and would be mapped onto the aircraft outline.

Using 3D data eliminates the vertical range ambiguity problem, because returns are mapped in the vertical dimension as well as in cross range and downrange.
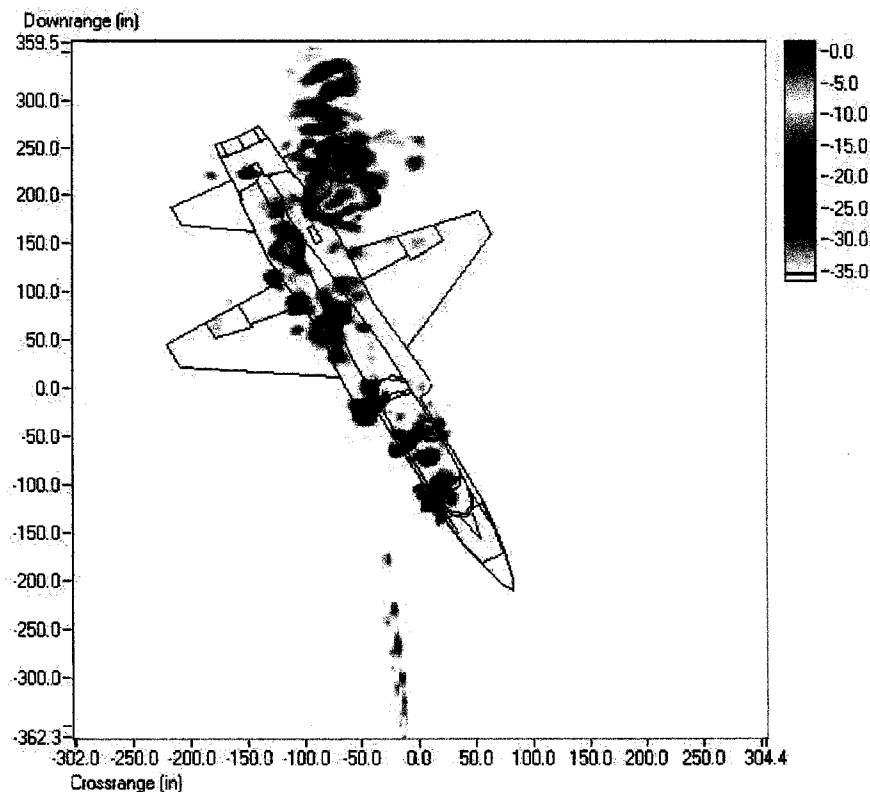

Figure 5. Typical 2D image using MHSR data.

The VRT software was used to generate the CAD model in Figure 6. This figure depicts the returns painted onto the external facets of the CAD model of the BQM-74E. Note the large return from the nose area. Note also that the return due to the mounting lugs and parachute cable are mapped to the top of the vehicle.
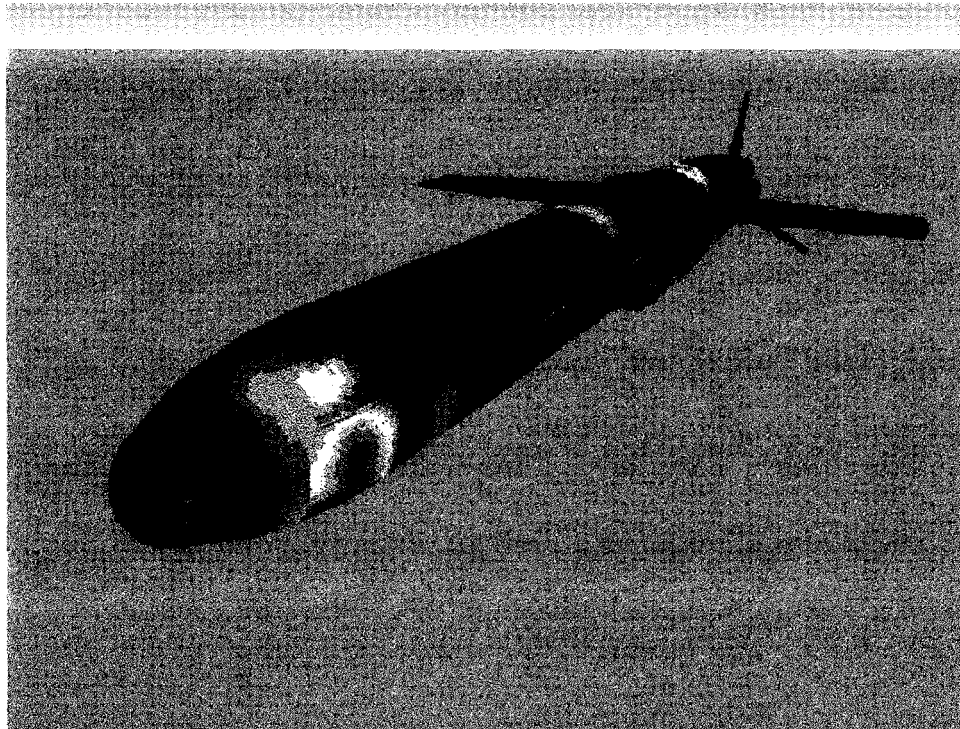
Figure 6. BQM-74E model with radar returns mapped onto the surface.

Figure 7 illustrates a T-38 model with the radar returns mapped on it. The engine inlets and canopy were covered with RAM to reduce their returns. The left view shows returns mapped to the top of the wing, and the right view shows the returns mapped to the bottom of the wing, clearly showing the effect of the landing gear and flap brackets.
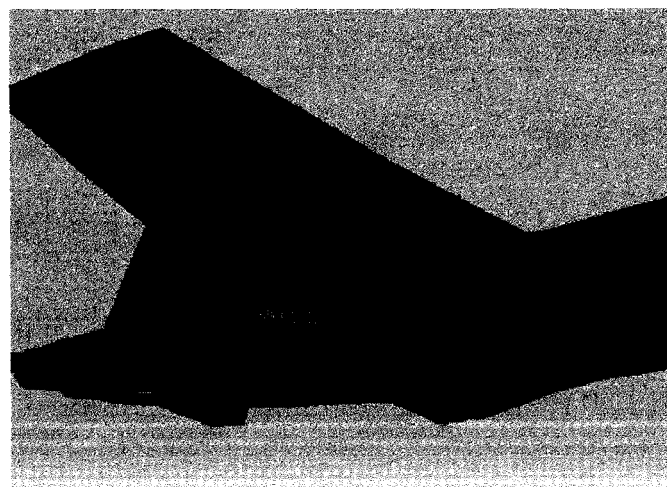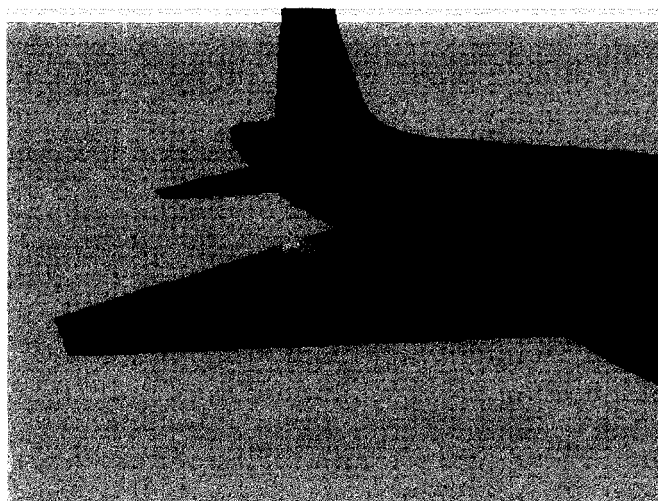
Figure 7. Note the difference in returns mapped to the top and the bottom of the T-38 model.

Another tool built into the 3D visualization software was the ability to "flag" the highest returns. The user can specify the number of flags. Figure 8 shows the eight highest returns for this configuration. The engine inlets were covered with RAM to eliminate their high return. Note the flags that appear "submerged" on the wing skin. These flags denote some of the highest return areas that were not mapped to the skin of the 3D CAD model, specifically the shrouded landing gear.
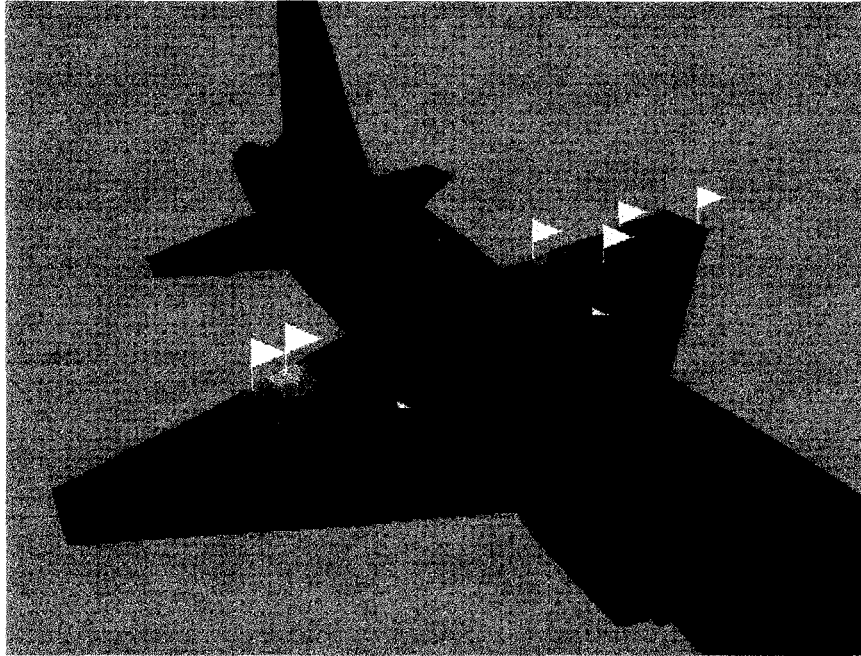

Figure 8. Flags can be depicted to show the location of the highest returns.

Figure 9. Multiple bounces of radar energy in the inlet causes the return to be mapped downrange.

Multi-bounce phenomena are a challenge when mapping returns to a 3D CAD model. Multi-bounce returns are delayed in time and therefore are mapped farther downrange than the point of the original return. The returns mapped on the tail surface of the T-38 in Figure 9, were caused by multiple bounces in the engine inlets. One way to depict this multi-bounce phenomenon is to provide a surface to map to, such as a horizontal plane that can be moved vertically.

In Figure 10, only returns that could not be mapped to the surface of the CAD model are displayed mapped to the horizontal plane as it moves vertically. The high return from the engine inlet cavity is displayed as bright colors aft of the aircraft fuselage. The high return also raises the noise floor, which results in the blue flash in front of the engine inlet.
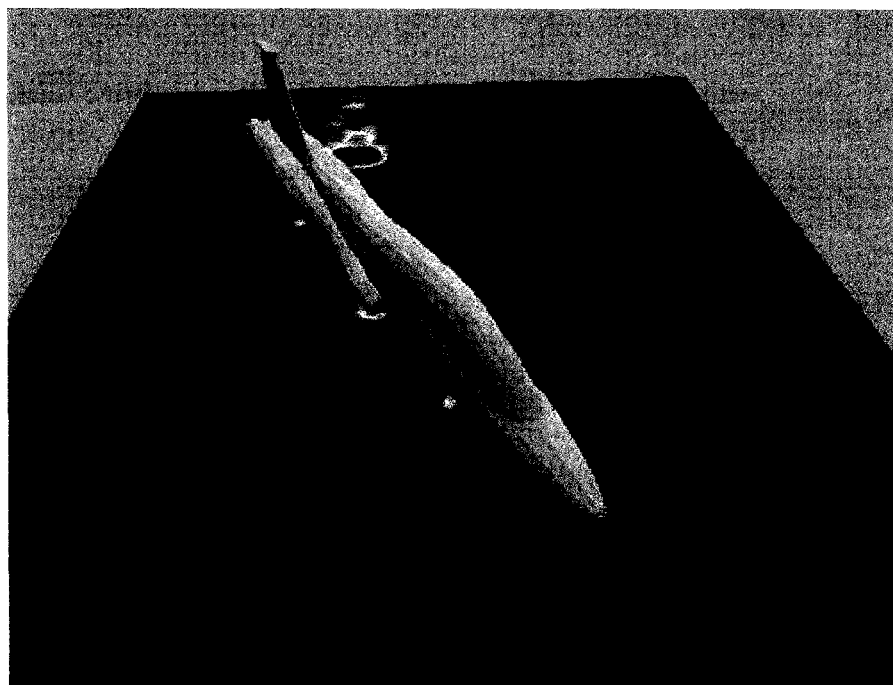
Figure 10. The horizontal plane provides a surface to map multiple-bounce radar returns that are delayed in time.

In conclusion, mapping radar returns to the surface of a 3D CAD model provides an intuitive way of visualizing the sources of radar returns. Since scanning the antenna in both vertical and horizontal dimensions collects three-dimensional data, the vertical ambiguity present in most traditional 2D images is eliminated. Specialized 3D software, developed by SCI for the Office of Naval Research, provides the link between 3D radar return data and commercial-off-the-shelf virtual reality software available to view CAD models. Multiple-bounce returns can be depicted using a moving plane to map returns delayed in time, and therefore outside of the CAD model surface.